An Ecohydrological Approach to Managing Intermittent and Ephemeral Streams on Department of Defense Lands in the Southwestern United States

Strategic Environmental Research and Development Program (SERDP) Project RC-1727, Resource Conservation and Climate Change Program Area

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Introduction

- Ephemeral and intermittent streams are the predominant fluvial forms in arid and semiarid (i.e. dryland) environments.
- Biodiversity and habitat value in drylands are considerably higher along ephemeral and intermittent stream riparian corridors in comparison to adjacent uplands.
- Knowledge of how these streams function is limited; specifically how the ecohydrological properties of these systems support wildlife.

Objective

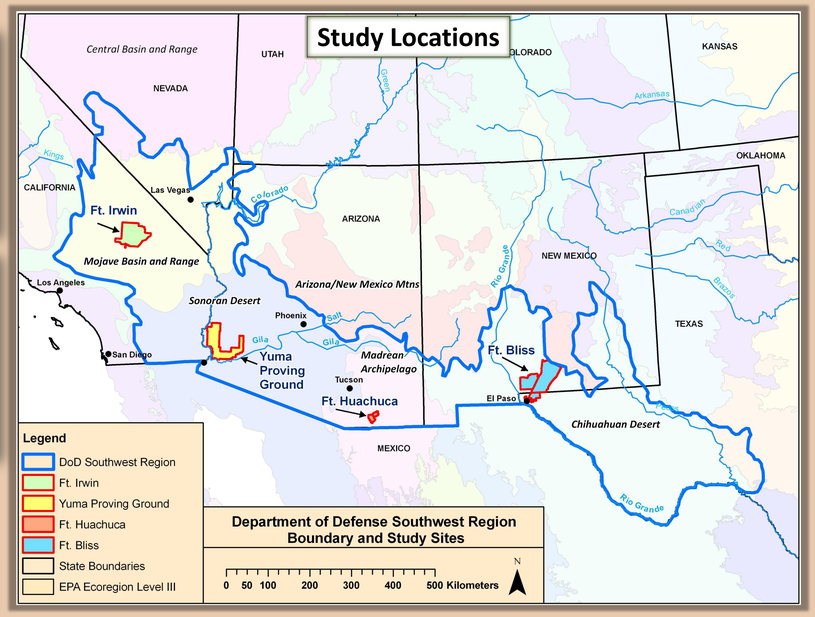
To inform decision making on DoD lands, this research developed an ecohydrologically-based classification and assessment methodology that:

1) Distinguishes ephemeral and intermittent stream types by a set of biotic and abiotic attributes.
2) Relates stream types to habitat values for threatened, endangered, and at-risk species (TER-S)
3) Allows DoD managers to evaluate the impacts of perturbations (e.g. climate change, military activities) on the hydrologic regimes of these systems and the species that depend upon them.

This research advances our understanding of how southwestern ephemeral and intermittent streams function, and creates a tool for assessing impacts of perturbations on the riparian corridors associated with these dryland systems.

Fort Irwin

Yuma Proving Ground



Fort Bliss

Fort Huachuca

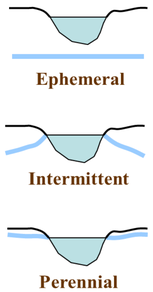
Technical Approach

- Gather GIS data, satellite imagery, LiDAR, climate, hydrologic data, and wildlife models.
- Collect field data on riparian vegetation, geomorphology, and wildlife habitat features.
- Evaluate multiple hydrologic, geomorphic and vegetation properties for all stream reaches at each installation.
- Analyze ecohydrological properties using statistical methods (i.e. CART, Clusters) to develop *stream types*.
- Link stream types and ecohydrological variables with wildlife habitat.
- Develop Stream Assessment methodology to link ecohydrological metrics with hydrologic modeling to evaluate the impacts of climate change, training activities and land management actions on channel characteristics and riparian habitat values.

Technical Background

Definitions of Ephemeral, Intermittent and Perennial Streams

- ***Ephemeral*** streams flow in response to localized rainfall, channel is at all times above groundwater.
- ***Intermittent*** streams flow seasonally due to snowmelt or spring flow, or geologic controls, may intersect groundwater.
- ***Perennial*** streams have year round flow, channel intersects groundwater.



Ecohydrological Variables Fort Huachuca Example

The stream systems at each installation were characterized using hydrologic, vegetation, and geomorphic variables for each 1-km stream reach. Each 1-km reach was "inundated" to a depth of 3m to represent the extent of the xeroriparian area, and the resultant polygon was used as the area of analysis.

Hydrologic Variables

- Flow Permanence (%): Percent of days in the year with flow in the channel; derived from AGWA/SWAT output for water yield (mm), using NEXRAD-MPE data
- Peak Flow or discharge (Qp, m^3/s): Obtained from AGWA/KINEROS outputs for the 5-, 10-, 25-, and 100-yr 1-hr design storms, based on NOAA Precipitation-Frequency estimates
- Rainfall Seasonality Index (RSI): Calculated from 30-year PRISM normals, as mean precip for wettest month / mean annual precip

Vegetation Variables

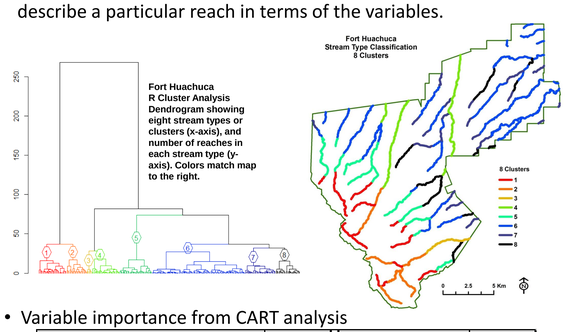
- Vegetation Cover (%): Derived from QuickBird satellite imagery, using the MSAVI2 vegetation index to classify 1-km reaches into bare ground vs. vegetation
- Mean Vegetation Index: Mean MSAVI2 value for each 1-km stream reach
- Vegetation Structure: Vegetation height derived from multi-return LiDAR data (subtract bare ground from canopy), and classified into 4 height classes: <1m, 1-4m, 4-12m, and >12m

Geomorphic Variables

- Elevation (m): Derived from LiDAR bare earth DEM
- Slope (%): Derived from LiDAR bare earth DEM
- Total Stream Power (TSP, kW/m): Calculated from AGWA/KINEROS Peak Flow and LiDAR derived slope
- Cumulative Area above the reach (m^2): From AGWA output
- Mean Riparian Width (m): Calculated from 1-km stream reach polygons for water surface at various inundation depths
- Entrenchment Ratio: Describes degree of channel entrenchment; Calculated from mean riparian widths 3m / 0.5m to represent Flood Prone Width / Bankfull Width

Fort Huachuca Stream Types

- All ecohydrological variables were used to determine the final eight Stream Types at Fort Huachuca using statistical and cluster analyses techniques, dendrograms, cluster validity tests in R, GIS examination of the mapped clusters, and site knowledge.
- CART was used to evaluate the clustering results to determine variable importance and threshold of each variable for each stream type. Thresholds can be used to extend the stream type classification to stream reaches not in the original analysis, or to describe a particular reach in terms of the variables.



- Variable importance from CART analysis

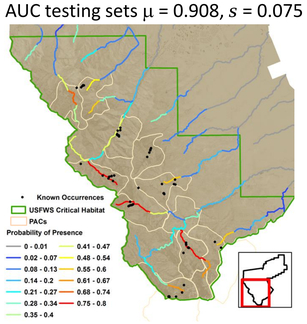
Variable	Score	Variable	Score
Peak Flow 25-yr 1-hr (m^3/s)	100.0	MSAVI2 Mean	39.4
Veg 4-12m (%)	64.4	Veg 1-4m (%)	38.9
Rainfall Seasonality index (RSI)	55.4	Flow Perm (%)	35.2
Elevation (m)	51.2	Percent Slope (%)	26.8
Total Stream Power 25-yr 1-hr (kW/m)	48.9	Width 2m (m)	21.0
Watershed Area (m^2)	48.1	Veg >12m (%)	17.6
Veg 0-1m (%)	45.9	Vegetation Cover (%)	11.9
Entrenchment Ratio 3m/0.5m	39.4		

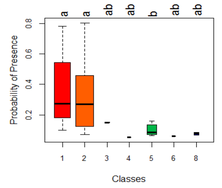
- Thresholds for some variables from CART decision tree showing percentage of stream reaches in each range, for the eight Stream Types. Bold values are higher percentages for that threshold range.

Stream Type	Peak Flow 25-yr 1-hr (m^3/s)					Veg 4 - 12 m (%)		Elevation (m)	
	<=112.07	<=262.24	<=350.71	<=785.56	>785.56	<=2.54	>2.54	<=1423.65	>1423.65
1	12.5	**45.8**	20.8	20.8	0.0	0.0	**100.0**	0.0	**100.0**
2	**93.1**	6.9	0.0	0.0	0.0	6.9	**93.1**	0.0	**100.0**
3	0.0	0.0	0.0	16.7	**83.3**	33.3	**66.7**	0.0	**100.0**
4	0.0	6.5	6.5	**87.1**	0.0	**83.9**	16.1	**74.2**	25.8
5	**75.0**	25.0	0.0	0.0	0.0	8.3	**91.7**	4.2	**95.8**
6	**81.4**	18.6	0.0	0.0	0.0	**95.3**	4.7	44.2	**55.8**
7	**97.3**	2.7	0.0	0.0	0.0	**81.1**	18.9	**100.0**	0.0
8	**88.7**	11.3	0.0	0.0	0.0	**98.4**	1.6	**75.8**	24.2

Wildlife Habitat Analysis

- **MaxEnt model for Mexican spotted owl presence, Fort Huachuca**
  - US Fish & Wildlife data for known occurrences
  - 4 variables: slope (%), veg 0-1m, veg 4-12m, veg >12m
  - Leave-one-out cross-validation
  - Higher probability of presence is related to steeper slopes, lower percent cover of veg 0-1m, and higher percent cover of veg 4-12m and >12m (stream types 1 and 2)
  - AUC testing sets $\mu = 0.908$, $s = 0.075$

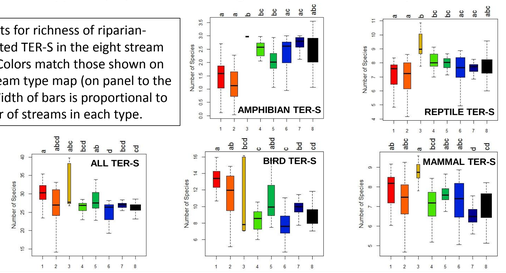




Mexican Spotted Owl
Above: Box Plot showing probability of presence in stream types within the modeling area
Left: Map of MaxEnt modeling results. PACs are "Protected Activity Centers" used by Ft. Huachuca for management

- **GAP species distribution models**
  - Stacked species models to evaluate response of TER-S to ecohydrological variables and stream types
  - Largest effect was elevation: higher elevations => decreased species richness
  - Large effect of mean vegetation index: Higher values (denser vegetation) => increased richness
  - Stream Type 3 had high overall richness
  - Stream Types 4, 6, and 8 had high amphibian and reptile richness

Box Plots for richness of riparian-associated TER-S in the eight stream types. Colors match those shown on the stream type map (on panel to the left). Width of bars is proportional to number of streams in each type.



Results and Conclusions

- Unique stream types were identified and classification trees produced for each installation
- Climate regime and geomorphology control stream type where annual rainfall amounts are very small or largely confined to one season per year (YPG and Fort Irwin)
- Vegetation variables control stream type where annual rainfall is higher or with a bimodal pattern (Forts Huachuca and Bliss), and vegetation structure is important to wildlife
- Hydrologic variables are important where annual rainfall is higher
- Stream types are a significant predictor of species richness and occurrence for some species: Gray Vireos (Bliss), screech owls and Mexican spotted owls (Huachuca), but not Desert tortoise or Burrowing owls (Irwin)

Importance of top 5 ecohydrological variables in Stream Type classification at each installation, with annual precipitation amounts

YPG		Fort Irwin		Fort Bliss		Fort Huachuca	
92.7 mm (3.65 in.)		110 mm (4.13 in.)		220 mm (8.66 in.)		381 m (15.6 in.)	
variable	score	variable	score	variable	score	variable	score
RSI	100.0	Watershed Area	100.0	Veg <0.5m	100.0	Qp 25yr 1hr	100.0
Width 2m	90.1	Elevation	95.9	Elevation	90.4	Veg 4-12m	64.4
Slope (%)	89.4	Width 2m	92.8	Veg 1-4m	90.0	RSI	55.4
Watershed Area	78.9	Vegetation Cover	82.9	Width 2m	72.9	Elevation	51.2
TSP 25yr 1hr	78.2	Slope (%)	72.7	Veg 4-12m	69.9	TSP 25yr 1hr	48.9

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